

WHAT IS CLAIMED IS:

1    1. For use with a multi-stage switch having  
2       - a plurality of central modules, each having  
3       outgoing links, and  
4       - a plurality of input modules, each including  
5           - a first number of input ports, each of the  
6           input ports having a second number of virtual  
7           output queues, and  
8           - outgoing links coupled with each of the  
9           plurality of central modules, and  
10          - a third number of sub-schedulers, each of the third  
11       number of sub-schedulers being able to arbitrate  
12       matching an input port with an outgoing link of one of  
13       the plurality of central modules via an outgoing link  
14       of the input module including the input port,  
15       a method for scheduling the dispatch of cells or packets  
16       stored in the virtual output queues, the method comprising:  
17           a) for each of the virtual output queues, maintaining  
18              a first indicator for indicating whether the virtual  
19              output queue is storing a cell awaiting dispatch  
20              arbitration; and  
21           b) for each of the sub-schedulers, performing a  
22              matching operation, if it has been reserved, to match  
23              a cell buffered at a virtual output queue with an  
24              outgoing link of one of the plurality of central  
25              modules via an outgoing link of the input module,  
26              wherein the matching operation includes:  
27                  i) for an input module, matching a non-empty  
28                  virtual output queue with an outgoing link of the  
29                  input module, and

30               ii) matching the outgoing link of the input  
31               module with an outgoing link of the associated  
32               central module,  
33               wherein each of the sub-schedulers requires more  
34       than one cell time slot to generate a match from its  
35       matching operation, and  
36               wherein the sub-schedulers can collectively  
37       generate a match result in each cell time slot.

1     2. The method of claim 1 wherein the act of matching a  
2     non-empty virtual output queue with an outgoing link of the  
3     input module includes

- 4               A) broadcasting a request for the non-empty  
5               virtual output queue to an arbiter of the  
6               sub-scheduler for each of the outgoing links  
7               of the input module;
- 8               B) selecting, with the arbiter, of the  
9               sub-scheduler, of each of the outgoing links  
10          of the input module, a non-empty virtual  
11          output queue that broadcast a request;
- 12          C) sending a grant to an arbiter, of the  
13          sub-scheduler, for the selected non-empty  
14          virtual output queue; and
- 15          D) selecting, with the arbiter, of the  
16          sub-scheduler, of the selected non-empty  
17          virtual output queue, an outgoing link of  
18          the input module from among the one or more  
19          outgoing links that sent a grant.

1     3. The method of claim 2 wherein the act of selecting,  
2     with the arbiter, of the sub-scheduler, of each of the  
3     outgoing links of the input module, a non-empty virtual

4 output queue that broadcast a request, is done in  
5 accordance with a round robin discipline.

1 4. The method of claim 3 wherein the round robin  
2 discipline moves through groups of virtual output queues,  
3 before moving through virtual output queues within each  
4 group.

1 5. The method of claim 2 wherein the acts of  
2 A) broadcasting a request for the non-empty  
3 virtual output queue to an arbiter of the  
4 sub-scheduler for each of the outgoing links  
5 of the input module;  
6 B) selecting, with the arbiter of the  
7 sub-scheduler of each of the outgoing links  
8 of the input module, a non-empty virtual  
9 output queue that broadcast a request;  
10 C) sending a grant to an arbiter of the  
11 sub-scheduler for the selected non-empty  
12 virtual output queue; and  
13 D) selecting, with the arbiter of the  
14 sub-scheduler of the selected non-empty  
15 virtual output queue, an outgoing link from  
16 among the one or more outgoing links that  
17 sent a grant,  
18 are performed at least twice within the third number of  
19 cell time slots.

1 6. The method of claim 1 wherein each of the  
2 sub-schedulers require no more than the third number of  
3 cell time slots to generate a match result from its  
4 matching operation.

1 7. The method of claim 1 further comprising:  
2       c) if a cell buffered at a virtual output queue has  
3       been successfully matched with its corresponding  
4       output port, informing the virtual output queue.

1 8. The method of claim 7 further comprising:  
2       d) for each of the virtual output queues, if the  
3       virtual output queue has been informed that it has  
4       been successfully matched with its corresponding  
5       output port, then dispatching its head of line cell.

1 9. The method of claim 1 wherein the first indicator, for  
2 each of the virtual output queues, for indicating whether  
3 the virtual output queue is storing a cell awaiting  
4 dispatch, is a count, and  
5               wherein the count is incremented upon learning  
6 that a new cell has arrived at the virtual output queue.

1 10. The method of claim 9 wherein the count is decremented  
2 when an available sub-scheduler is reserved for considering  
3 a head of line cell at a corresponding virtual output  
4 queue.

1 11. The method of claim 1 further comprising:  
2       c) for each of the sub-schedulers, maintaining a  
3       second indicator for each of the virtual output  
4       queues, for indicating whether the sub-scheduler is  
5       available or reserved,  
6               wherein the second indicator, for each of the  
7       sub-schedulers, is set to indicate that the associated  
8       sub-scheduler is reserved if the first indicator indicates

9 that a corresponding virtual output queue is storing a cell  
10 awaiting dispatch arbitration.

1 12. The method of claim 1 further comprising:  
2 c) for each of the sub-schedulers, maintaining a  
3 second indicator for each of the virtual output  
4 queues, for indicating whether the sub-scheduler is  
5 available or reserved,  
6 wherein the second indicator, for each of the  
7 sub-schedulers, is set to indicate that the associated  
8 sub-scheduler is available if the associated sub-scheduler  
9 matches a cell buffered at a virtual output queue with its  
10 corresponding output port.

1 13. The method of claim 1 further comprising:  
2 c) for each of the sub-schedulers, maintaining a  
3 second indicator for each of the virtual output  
4 queues, for indicating whether the sub-scheduler is  
5 available or reserved,  
6 wherein the second indicator is set to indicate  
7 that a p<sup>th</sup> sub-scheduler is reserved if the first indicator  
8 indicates that a corresponding virtual output queue is  
9 storing a cell awaiting dispatch arbitration,  
10 wherein p is set to the current cell time slot  
11 modulo the third number.

1 14. For use with a multi-stage switch including  
2 - a plurality of central modules, each including  
3 outgoing links towards output modules, the output  
4 modules collectively including a first number of  
5 output ports,

6        - a plurality of input modules, each including  
7        virtual output queues and outgoing links coupled with  
8        each of the plurality of central modules, the input  
9        modules collectively including a second number of  
10      input ports,

11      a dispatch scheduler comprising:

12        a) a third number of sub-schedulers; and  
13        b) a first indicator, associated with each of the  
14        virtual output queues, for indicating whether the  
15        virtual output queue is storing a cell awaiting  
16        dispatch arbitration,

17            wherein each of the sub-schedulers is adapted to  
18        perform a matching operation, if it has been reserved, to  
19        match a cell buffered at a virtual output queue with its  
20        corresponding output port, and includes:

21            i) for an input module, means for matching a  
22        non-empty virtual output queue with an outgoing  
23        link of the input module, and  
24            ii) means for matching the outgoing link of the  
25        input module with an outgoing link of the  
26        associated central module,

27            wherein each of the sub-schedulers requires more  
28        than one cell time slot to generate a match from its  
29        matching operation, and

30            wherein the sub-schedulers can collectively  
31        generate a match result in each cell time slot.

1        15. The dispatch scheduler of claim 14 wherein the means  
2        for matching a non-empty virtual output queue with an  
3        outgoing link of the input module include  
4            A) means for broadcasting a request for the  
5        non-empty virtual output queue to an arbiter

6                   for each of the outgoing links of the input  
7                   module;  
8                   B) for each of the outgoing links of the  
9                   input module, an arbiter for selecting a  
10                  non-empty virtual output queue that  
11                  broadcast a request;  
12                  C) means for sending a grant to an arbiter  
13                  for the selected non-empty virtual output  
14                  queue; and  
15                  D) for the selected non-empty virtual  
16                  output queue, an arbiter for selecting an  
17                  outgoing link of the input module from among  
18                  the one or more outgoing links of the input  
19                  module that sent a grant.

1       16. The dispatch scheduler of claim 14 wherein each of the  
2       sub-schedulers require no more than the third number of  
3       cell time slots to generate a match result from its  
4       matching operation.

1       17. The dispatch scheduler of claim 14 wherein if a cell  
2       buffered at a virtual output queue has been successfully  
3       matched with its corresponding output port, the virtual  
4       output queue is so informed.

1       18. The dispatch scheduler of claim 14 wherein if a cell  
2       buffered at a virtual output queue has been successfully  
3       matched with its corresponding output port, its head of  
4       line cell is dispatched.

1       19. The dispatch scheduler of claim 14 wherein the first  
2       indicator, for each of the virtual output queues, for

3 indicating whether the virtual output queue is storing a  
4 cell awaiting dispatch arbitration, is a count, and  
5 wherein the count is incremented upon learning  
6 that a new cell has arrived at the virtual output queue.

1 20. The dispatch scheduler of claim 19 wherein the count  
2 is decremented when an available sub-scheduler is reserved  
3 for considering a head of line cell at a corresponding  
4 virtual output queue.

1 21. The dispatch scheduler of claim 14 further comprising:  
2 c) a second indicator for each of the virtual output  
3 queues and for each of the sub-schedulers, indicating  
4 whether the sub-scheduler is available or reserved,  
5 wherein the second indicator, for each of the  
6 sub-schedulers, is set to indicate that the associated  
7 sub-scheduler is reserved if the first indicator indicates  
8 that a corresponding virtual output queue is storing a cell  
9 awaiting dispatch arbitration.

1 22. The dispatch scheduler of claim 14 further comprising:  
2 c) a second indicator for each of the virtual output  
3 queues and for each of the sub-schedulers, indicating  
4 whether the sub-scheduler is available or reserved,  
5 wherein the second indicator, for each of the  
6 sub-schedulers, is set to indicate that the associated  
7 sub-scheduler is available if the associated sub-scheduler  
8 matches a cell buffered at a virtual output queue with its  
9 corresponding output port.

1   23. The dispatch scheduler of claim 14 further comprising:  
2       c) a second indicator for each of the virtual output  
3       queues and for each of the sub-schedulers, indicating  
4       whether the sub-scheduler is available or reserved,  
5               wherein the second indicator is set to indicate  
6       that a p<sup>th</sup> sub-scheduler is reserved if the first indicator  
7       indicates that a corresponding virtual output queue is  
8       storing a cell awaiting dispatch, and  
9               wherein p is set to the current cell time slot  
10     modulo the third number.

1   24. The dispatch scheduler of claim 14 wherein the arbiter  
2   of each of the outgoing links of the input module for  
3   selecting a non-empty virtual output queue that broadcast a  
4   request, operates in accordance with a round robin  
5   discipline.

1   25. The dispatch scheduler of claim 24 wherein the round  
2   robin discipline moves through groups of virtual output  
3   queues, before moving through virtual output queues within  
4   each group.

1   26. The dispatch scheduler of claim 14 wherein the means  
2   for matching a non-empty virtual output queue with an  
3   outgoing link of the input module performs multiple  
4   iterations of matching a non-empty virtual output queue  
5   with an outgoing link of the input module within the third  
6   number of cell time slots.